

REMARKS

This is in response to the Office Action dated May 15, 2010. Claim 1 is amended to incorporate the features of claims 2, 3, and 5. The amendment is also supported by disclosure in paragraph [0032] of the specification. Claims 2-5 are cancelled, without prejudice. No new matter is introduced by this Amendment. Claims 1 and 6-12 are pending in the application, of which claims 7-12 stand withdrawn from consideration.

The present invention

The invention delimited in independent claim 1 hereinabove is characterized in that the polymer comprises a certain amount of a specific crosslinkable functional group. Specifically, in the present invention, the crosslinkable functional group is limited to “a combination of an epoxy group and a sulfonic acid group or a salt thereof” – that is, (i) a combination of an epoxy group and a sulfonic acid group or (ii) a combination of an epoxy group and a sulfonic acid salt moiety. In accordance with disclosure in paragraphs [0029] and [0030] of the specification, a sulfonic acid group and an epoxy group may be crosslinked to one another by heat treatment.

The prior art

Claims 1-6 were rejected under 35 U.S.C. 103(a) as being unpatentable over US 6,734,246 (Weitzel) or US 6,759,490 (Gerst). Office Action, pages 2-4. Claims 1-6 were rejected under 35 U.S.C. 103(a) as being unpatentable over US 2004/0062989 (Ueno). Office Action, pages 4-5. Claims 1-4 and 6 were rejected under 35 U.S.C. 103(a) as being unpatentable over US 6,656,633 (Yamakawa) or US 6,884,837 (Kohlhammer) or US 4,473,678 (Fink). Office Action, pages 5-7. The rejections are respectfully traversed.

None of Weitzel, Gerst, Ueno, Yamakawa, Kohlhammer, or Fink teaches or suggests a binder that includes Applicants' specific crosslinkable combination. This feature of the present invention provides unexpected benefits, as may be seen, for instance, from Example 4 in the specification. An electrode was produced using the binder of Example 4 in accordance with the present invention, and an electric double layer capacitor was produced using the electrode so obtained. The electrode and the capacitor has extremely good performance characteristics. For

instance, the peel strength of the electrode was 0.100 N/cm, the electrostatic capacity of the capacitor was 61.0 F/g, and the internal resistance of the capacitor was 3.12 Ω F. This compares favorably to the results obtained in the other Examples not representative of the invention claimed hereinabove.

Further evidence¹ of the unexpected beneficial properties provided by Applicants' invention is presented in the 'Experimental report' which accompanies this Amendment.

The electrode and the electric double layer capacitor of ADDITIONAL EXAMPLES 1-4 are all produced by using the binder of the present invention. ADDITIONAL EXAMPLE 1 corresponds to Example 1 in the application. In ADDITIONAL EXAMPLES 2-4, the amount of the crosslinkable functional group is changed within the scope of the present invention – that is, within the range 0.1-10% by weight.

As can be seen from ADDITIONAL EXAMPLES 2-4, it is clear that the electrode and the electric double layer capacitor made with the binder of the present invention have extremely high performance characteristics (especially with respect to peel strength of the electrode and electrostatic and internal resistance of the capacitor). Furthermore, when the amount of the crosslinkable functional group is too high (e.g., more than 10%), the polymer does not provide a film having a tensile stress of 2 MPa or less when the film is elongated to 100% and does not provide a film having an elongation at break of 450% or more. That is, when the amount of the crosslinkable functional group is more than 10%, the obtained binder does not meet the requirements of the present invention.

In conclusion, as to the present invention:

- (1) the binder comprises a specific crosslinkable combination which is neither taught nor suggested by the prior art;
- (2) the amount of the crosslinkable functional group specified in Applicants' claim 1 is the range which achieves the specified tensile stress and elongation properties through which

¹ Applicants intend to present the data in verified form in a Declaration under 37 CFR 1.132 to be filed shortly.

the binder becomes properly flexible; and

(3) as a result of Applicants' invention claimed hereinabove, electrodes and electric double layer capacitors with extremely high performance characteristics may be manufactured by using the binder.


It is manifest from the above discussion that the presently claimed invention is not placed in the possession of persons of ordinary skill in the art by any combination or subcombination of the Weitzel, Gerst, Ueno, Yamakawa, Kohlhammer, and Fink references. Withdrawal of all rejections of record is in order and is earnestly solicited.

Should there be any outstanding matters that need to be resolved in the present application, the Examiner is respectfully requested to contact Garth M. Dahlen, PhD, Registration No. 43,575, at the telephone number of the undersigned below to conduct an interview in an effort to expedite prosecution in connection with the present application.

If necessary, the Director is hereby authorized in this, concurrent, and future replies to charge any fees required during the pendency of the above-identified application or credit any overpayment to Deposit Account No. 02-2448.

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Respectfully submitted,

By  #42,874

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Attachment: Experimental Report (5 pages)

<OBJECT>

An object of this experimental report is to prove that the electrode with the binder of the present invention and the electric double layer capacitor with the electrode have extremely high performance.

<EXPERIMENT>

ADDITIONAL EXAMPLE 1

ADDITIONAL EXAMPLE 1 is corresponding to the Example 4 of the present application.

Into a reactor equipped with a stirrer were supplied 70 parts of ion exchange water, 0.2 part of sodium dodecylbenzenesulfonate, and 0.3 part of potassium peroxodisulfate, and then a gas part therein was purged with nitrogen gas. The temperature of the system was raised to 60°C. In another container, 50 parts of ion exchange water, 0.5 part of sodium dodecylbenzenesulfonate, 88.5 parts of butyl acrylate, 10 parts of acrylonitrile, 1 part of glycidyl methacrylate, and 0.5 part of 2-acrylamide-2-methylpropanesulfonic acid were mixed to yield a monomer mixture. This monomer mixture was continuously added to the above-mentioned reactor over 4 hours to conduct polymerization. During the addition, the reaction was conducted at 60°C. After the end of the addition, the inside of the system was stirred at 70°C for 3 hours, and then the reaction was ended. The polymerization conversion ratio was 98.5%. The composition ratio of the resultant polymer was consistent with the provided ratio of the monomers. The Tg of the resultant polymer is shown in Table 1. The reaction solution was cooled to 25°C and then thereto was added ammonia water to adjust the pH to 8. Thereafter, steam was introduced thereinto, so as to remove the monomers unreacted. Next, the resultant was concentrated to set the solid concentration to 40% so as to yield a binder composition A as a dispersion of an acrylate-based elastomer in water. This binder composition A was used to yield a polymer film. The tensile stress when the film was elongated at a ratio of 100%, and the elongation when the film was cut were measured.

Next, a planetary mixer was used to mix 50 parts of acetylene

black (powdery Denka Black, manufactured by Denki Kagaku Kogyo Kabushiki Kaisha) as an electroconductivity additive, 200 parts of a 5% carboxymethylcellulose solution in water (Cellogen 7A, manufactured by Daiichi Kogyo Seiyaku Co., Ltd.) as a dispersing agent, and 50 parts of water so as to disperse the electroconductivity additive, thereby yielding a dispersion of the electroconductivity additive, the solid concentration therein being 20%. An appropriate amount of water was added to 30 parts of the resultant dispersion, 100 parts of high-purity activated carbon powder having an average particle diameter of 5 μm and a specific surface area of 2000 m^2/g as an active material for an electrode, and 7.5 parts of the binder composition A, and then the resultant was mixed in a planetary mixer with appropriate amount of water to yield a slurry composition.

A doctor blade was used to apply the resultant slurry composition to an aluminum foil having a thickness 20 μm and the resultant was dried at 60°C for 20 minutes and at 120°C for 20 minutes, and subjected to roll pressing, thereby yielding an electrode having a thickness of 120 μm . The resultant electrode was heated at 150°C under a reduced pressure for 6 hours. The electrode density and the peel strength of the resultant electrode are shown in Table 1.

The electrode yielded as described above was cut into circles having a diameter of 12 mm. Electrode layer faces of these two electrodes were made opposite to each other, and a separator made of a rayon-based porous circular film of 16 mm in diameter and of 35 μm in thickness was sandwiched therebetween. This was put together with a spacer made of stainless steel into a coin-shaped outside container made of stainless steel (diameter: 20 mm, height: 1.8 mm, and thickness of the stainless steel: 0.25 mm). An electrolytic solution was incorporated therein without leaving air. Thereafter, the container was sealed up to produce an electric double layer capacitor. The used electrolytic solution was a solution wherein triethylmonomethylammonium tetrafluoroborate was dissolved in propylene carbonate at a concentration of 1.8 mol/L. The storage of the electrode after the heat-treatment and the fabrication of the capacitor were performed in a dry room

having a dew-point temperature of -60°C . The electrostatic capacity and the internal resistance of the resultant electric double layer capacitor are shown in Table 1.

ADDITIONAL EXAMPLE 2

In ADDITIONAL EXAMPLE 2, 89.2 parts of butyl acrylate, 10 parts of acrylonitrile, 0.5 part of glycidyl methacrylate, and 0.3 part of 2-acrylamide-2-methylpropanesulfonic acid were mixed to yield a monomer mixture. Other than this, the polymerization process was carried out in the same manner as that of ADDITIONAL EXAMPLE 1 to obtain a polymer. The T_g of the resultant polymer is shown in Table 1. The reaction solution was cooled to 25°C and then thereto was added ammonia water to adjust the pH to 8. Thereafter, steam was introduced therein, so as to remove the monomers unreacted. Next, the resultant was concentrated to set the solid concentration to 40% so as to yield a binder composition B as a dispersion of an acrylate-based elastomer in water. This binder composition B was used to yield a polymer film. The tensile stress when the film was elongated at a ratio of 100%, and the elongation when the film was cut were measured. Then, other than using the binder composition B instead of using the composition A, the same process of above ADDITIONAL EXAMPLE 1 was applied in order to obtain the slurry composition, the electrode and the electric double layer capacitor, and evaluated the performance of them. The result is shown in Table 1.

ADDITIONAL EXAMPLE 3

In ADDITIONAL EXAMPLE 3, 86.5 parts of butyl acrylate, 10 parts of acrylonitrile, 3.0 part of glycidyl methacrylate, and 0.5 part of 2-acrylamide-2-methylpropanesulfonic acid were mixed to yield a monomer mixture. Other than this, the same polymerization process of above ADDITIONAL EXAMPLE 1 was applied thereby obtaining the polymer. The T_g of the resultant polymer is shown in Table 1. The reaction solution was cooled to 25°C and then thereto was added ammonia water to adjust the pH to 8. Thereafter, steam was introduced therein, so as to remove the monomers unreacted. Next, the resultant was concentrated to set

the solid concentration to 40% so as to yield a binder composition C as a dispersion of an acrylate-based elastomer in water. This binder composition C was used to yield a polymer film. The tensile stress when the film was elongated at a ratio of 100%, and the elongation when the film was cut were measured. Then, other than using the binder composition C instead of using the composition A, the same process of above ADDITIONAL EXAMPLE 1 was applied in order to obtain the slurry composition, the electrode and the electric double layer capacitor, and evaluated the performance of them. The result is shown in Table 1.

ADDITIONAL EXAMPLE 4

In ADDITIONAL EXAMPLE 4, 82.0 parts of butyl acrylate, 10 parts of acrylonitrile, 6.5 part of glycidyl methacrylate, and 1.5 part of 2-acrylamide-2-methylpropanesulfonic acid were mixed to yield a monomer mixture. Other than this, the same polymerization process of above ADDITIONAL EXAMPLE 1 was applied thereby obtaining the polymer. The Tg of the resultant polymer is shown in Table 1. The reaction solution was cooled to 25°C and then thereto was added ammonia water to adjust the pH to 8. Thereafter, steam was introduced thereinto, so as to remove the monomers unreacted. Next, the resultant was concentrated to set the solid concentration to 40% so as to yield a binder composition D as a dispersion of an acrylate-based elastomer in water. This binder composition D was used to yield a polymer film. The tensile stress when the film was elongated at a ratio of 100%, and the elongation when the film was cut were measured. Then, other than using the binder composition D instead of using the composition A, the same process of above ADDITIONAL EXAMPLE 1 was applied in order to obtain the slurry composition, the electrode and the electric double layer capacitor, and evaluated the performance of them. The result is shown in Table 1.

<RESULT>

(Table 1)

	ADDITIONAL EXAMPLE 1	ADDITIONAL EXAMPLE 2	ADDITIONAL EXAMPLE 3	ADDITIONAL EXAMPLE 4
The amount (wt %) of crosslinkable functional group	1.5	0.8	3.5	8.0
T _g (°C)	-43	-44	-43	-41
Tensile stress(MPa) at the time of the 100% elongation	0.8	0.8	1.0	1.4
Elongation(%) at the time of the cutting	700	700	650	550
Electrode density(g/cm ³)	0.640	0.640	0.640	0.630
Peel strength(N/cm)	0.100	0.100	0.120	0.150
Electrostatic capacity(F/g)	61.0	61.0	62.0	60.5
Internal resistance(ΩF)	3.12	3.12	3.12	3.20

<DISCUSSION>

As shown in Table 1, it is clear that the binder of ADDITIONAL EXAMPLES 1-4 has desirable flexibility. It is also clear that the electrode with the binder and the electric double layer capacitor having the electrode show extremely high performance, that is, high electrode density, high peel strength, high electrostatic capacity and low internal resistance.